South African seed oils are safe for human consumption

Opperman M,[1] MSc, PhD (RD SA)
Benadé AJS,[1] DSc, **Abrecht CF,**[2] PhD(Biochemistry); **Matsheka LL,**[1] BTech:Chemistry
[1]Functional Foods Research Unit, Department of Biotechnology and Consumer Science, Faculty of Applied Science
Cape Peninsula University of Technology, Cape Town
[2]Cancer Association of South Africa, Cape Town
Correspondence to: Maretha Opperman, e-mail: oppermanm@cput.ac.za
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Abstract

Objectives: A diet that is high in fat and low in carbohydrates is advocated in the recently published *The Real Meal Revolution*. A suggestion was made in this publication that seed oils are toxic. The authors stated that available seed oils on the South African market were high in trans-fatty acid (TFA), as well as being genetically modified, and thus should be avoided. We compared three oils, i.e. canola, sunflower and olive oil, against internationally accepted standards, to determine the quality of these oils using gaschromatographic analysis, to determine whether or not there was any foundation to the statement pertaining to the toxicity of South African seed oils. Reported parameters included the fatty acid profile, TFA content, peroxide level and conjugated diene (CD) content.

Design: Samples were purchased from local retail stores. Two independent researchers de-identified the oils, and stored them in numbered containers under nitrogen until commencement of the analysis. Hence, a blind sample of oils was received.

Outcome measures: Twelve (n = 12) olive oil, 15 (n = 15) canola oil and 7 (n = 7) sunflower oil samples were subjected to analysis. CD and peroxide levels were conducted spectrophotometrically, and fatty acid content determined by gas liquid chromatography.

Results: The total TFA content of the three types of sampled oils was below 0.5%, and the peroxide (meq O_2/kg) and CD levels (µmol/g) were within allowable limits, as described in the Codex Standard for Named Vegetable Oils, as well as previous publications.

Conclusion: The results demonstrated that the South African seed oils included in this analysis contained a negligible amount of TFA, adhered to international recommendations with respect to fatty acid content, and were well within the safe range for oxidation products. Therefore, the statement that South African seed oils are toxic is inaccurate, unscientific and without merit.

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Introduction

An impression has been created over the past two years that seed oils are toxic and should be eliminated from the diet. This opinion was fuelled by a statement in *The Real Meal Revolution,*[1] that sunflower and canola oil, among others, are toxic, and should be avoided. A high trans-fatty acid (TFA) content of seeds oils,[2] omega-6 to omega-3 fatty acid ratio,[3] the so-called resemblance to mustard gas, and the genetic modification (GM)[4] of seed oils were some of the reasons provided for the toxicity (Creed SA, 2015, personal communication with Albrecht CF). However, seed oils form an integral part of the South African diet, and contribute to the dietary intake of polyunsaturated fatty acid (PUFA) and monounsaturated fatty acid (MUFA), as well as vitamin E. They are also relatively affordable. PUFA,[5] e.g. seed oil and nuts, and MUFA,[6] e.g. olive oil and avocado oil, have consistently been associated with several health benefits. Essential fatty acids are also present in PUFA.

Compared to animal fat, seed oils contain a higher percentage of total fatty acids than PUFAs and MUFAs, with a smaller amount of saturated fat. PUFA and MUFA is responsible for the fluidity of seed oils at room temperature. PUFA is the source of omega-6 and omega-3 fatty acid, which are also essential fatty acids, meaning that the body cannot produce them, and needs to obtain them via the diet.[7] Conclusive evidence for the replacement of saturated fat with omega-6 fatty acid and/or MUFA in the diet, and vice versa, to reduce the risk of disease, is still not available.[8] However, current literature provides stronger evidence for the health benefits of PUFAs and MUFAs than those of saturated fat.[5,6] It has been suggested in a more recent approach that the same chemical class of fatty acid may elicit a different physiological response. Therefore, making generalisations about fatty acid according to the degree of unsaturation or the configuration of double bonds alone might not be advisable.[8]

Seed oils, such as canola and flaxseed oil, contain moderate to high amounts of plant-derived omega-3 fatty acid, indicated to be beneficial to heart health. Canola oil was authorised with a qualified health claim from the US Food and Drug Administration, owing to its

high levels of alpha-linolenic acid (ALA), a plant-derived omega-3 fatty acid, and its positive effect on total cholesterol and low-density lipoprotein (LDL) cholesterol, biomarkers of coronary heart disease.[9] ALA can be converted, although to a limited extent, to longer-chain PUFA, essential for human health.

Besides maize and wheat, sunflower is the third largest grain crop produced in South Africa. An average of 643 000 tons of sunflower seed were produced annually between 2004 and 2013, and the gross value was approximated to be R1.93 billion per annum.[10] In addition, canola oil represents approximately 6% of the edible oil market in South Africa, and is also an ingredient in a range of products. The value of products in the edible oil market alone is approximately R400 million. In addition, canola oil is locally produced. Therefore, these accusations that seed oils were toxic and should be avoided caused such concern that our group decided to investigate the validity of such a statement. Three vegetable oils were included in this analysis, of which two were seed oils, i.e. canola and sunflower oil, and the third, olive oil. Their content was compared against that of internationally accepted standards to determine their quality, and to determine whether or not there was any foundation to the statement on the toxicity of South African seed oils. Reported parameters include the fatty acid profile, TFA content, peroxide level

Table I: The fatty acid content of the oils compared to the respective Codex Standard for Named Vegetable Oils

Descriptor	Olive oil*	Codex Standard	Canola oil*	Codex Standard	Sunflower oil*	Codex Standard
	n = 12		n = 15		n = 7	
C14:0	0.03 ± 0.01	< 0.10	0.08 ± 0.01	ND-0.20	0.10 ± 0.02	ND-0.20
C16:0	10.68 ± 1.63	7.50-20.00	4.03 ± 0.25	2.50-7.00	5.83 ± 0.26	5.00-7.60
C16:1 trans	0.11 ± 0.02	-	0.05 ± 0.01	-	0.23 ± 0.11	-
C16:1	0.79 ± 0.25	0.30-3.50	0.22 ± 0.01	ND-0.60	0.09 ± 0.02	ND-0.30
C18:0	2.04 ± 0.37	0.50-5.00	1.61 ± 0.09	0.80-3.00	3.64 ± 1.03	2.70-6.50
C18:1 trans	0.06 ± 0.03	-	0.08 ± 0.03	-	0.10 ± 0.04	-
C18:1 n-9	74.87 ± 4.14	55.00-83.00	60.20 ± 1.68	51.00-70.00	29.40 ± 3.62	14.00-39.40
C18:1 n-11	1.39 ± 1.29	-	2.79 ± 0.15	-	0.35 ± 0.18	-
C18:2 trans	0.03 ± 0.01	-	0.08 ± 0.04	-	0.02 ± 0.01	-
C18:2 n-6	8.49 ± 2.38	3.50-21.00	19.02 ± 1.87	15.00-30.00	58.66 ± 2.56	48.30-74.00
C18:3 n-3	0.65 ± 0.08	< 1.50	8.94 ± 0.72	5.00-14.00	0.14 ± 0.06	ND-0.30
C20:0	0.29 ± 0.04	< 0.80	0.37 ± 0.05	0.20-1.20	0.22 ± 0.05	0.10-0.50
C20:1 trans	0.00 ± 0.01	-	0.01 ± 0.01	-	0.00 ± 0.00	-
C20:1	0.27 ± 0.04	-	1.05 ± 0.09	0.10-4.30	0.14 ± 0.02	ND-0.30
C20:2	0.01 ± 0.01	-	0.06 ± 0.01	ND-0.10	0.04 ± 0.02	ND
C20:4 n-6	0.10 ± 0.02	-	0.01 ± 0.01	-	0.59 ± 0.27	-
C22:0	0.00 ± 0.00	< 0.30	0.28 ± 0.03	ND-0.60	0.00 ± 0.00	0.30-1.50
C22:1 trans	0.00 ± 0.00	-	0.01 ± 0.02	-	0.03 ± 0.07	-
C22:1	0.01 ± 0.01	-	0.09 ± 0.14	ND-2.00	0.01 ± 0.01	ND-0.30
C22:2	0.00 ± 0.00	-	0.00 ± 0.00	ND-0.10	0.01 ± 0.01	ND-0.30
C20:5 n-3	0.01 ± 0.01	-	0.02 ± 0.01	-	0.01 ± 0.02	-
C22:6 n-3	0.00 ± 0.00	-	0.03 ± 0.03	-	0.00 ± 0.00	-
C24:0	0.02 ± 0.02	< 0.10	0.14 ± 0.01	ND-0.30	0.23 ± 0.09	ND-0.50
C24:1	0.03 ± 0.02	-	0.28 ± 0.10	ND-0.40	0.03 ± 0.01	ND
Total SFA	13.08		6.50		10.10	
Total MUFA	77.50		64.80		30.40	
Total PUFA	9.40		28.70		59.50	
Total TFA	0.20 ± 0.04		0.22 ± 0.07		0.40 ± 0.05	
PUFA:SFA	0.72		4.39		5.91	
MUFA:PUFA	8.24		2.26		0.51	
Total n-6	8.72		19.59		59.35	
Total n-3	0.67		9.04		0.18	
n-6:n-3**	13.02		2.17		329.73	

Codex Standard: Codex Standard for Named Vegetable Oils, MUFA: monounsaturated fatty acid, ND: not detected, PUFA: polyunsaturated fatty acid, SFA: saturated fatty acid, TFA: trans-fatty acid
*The values are expressed as a percentage of total fatty acid
**The n-6:n-3 ratio is calculated as the sum of n-6 fatty acids (18:2 n-6; 18:3 n-6; 20:2 n-6; 20:3 n-6; 20:4 n-6; 22:2 n-6; 22:4 n-6; 22:5 n-6) to the sum of the n-3 fatty acids (18:3 n-3; 20:3 n-3; 20:5 n-3; 22:5 n-3 and 22:6 n-3)

and conjugated diene (CD) content. The prevalence of potentially undesired fatty acid, such as erucic acid and TFA, is highlighted by the fatty acid profile, while the peroxide level and CD content indicate the presence of primary oxidation products in the oil.

Method

Twelve olive oils, 15 canola oils and seven sunflower oils available on the South African retail market were included in the analysis. Seven of the canola oil samples were analysed in 2013, and eight in 2015. The 2015 analysis was repeated on the same brands analysed in 2013. All of the oil was locally produced. Market representation of the analysed samples was 50-60% for olive oil, 100% for canola oil and 80-90% for sunflower oil. Two independent researchers de-identified the oils, and stored them in numbered containers in nitrogen at 4 °C until commencement of the analysis, hence a blind sample of oils was received. Products from a variety of sunflower, canola and olive oil brands were analysed. House brands, in alphabetical order, included B-well, Checkers, Excella, Food Lover's Market, Pick n Pay, Shoprite, Spar, Sunfoil and Woolworths. Oils with a best-before date of between 12 and 24 months from the time of purchase were selected. The CD content, peroxide value and fatty acid analysis was determined according to the methods described in previous publications.[11]

Results

The percentage of fatty acid content of the canola and sunflower oils was compared to the Codex Standard for Named Vegetable Oils,[12] while the olive oil was compared to the Codex Standard for Named Vegetable Oils for olive oil, virgin olive oil, refined olive oil and refined olive pomace oil.[13] The results are summarised in Table I, while the inter-assay coefficients of variation of the different fatty acid are displayed in Table II.

Fatty acid composition

All three types of oils adhered to the respective standards in terms of the permissible individual fatty acid content when compared against the Codex Standard for Named Vegetable Oils, as shown in Table I.

Trans-fat acid content

Standards are not indicated for TFA in the Codex Standard for Named Vegetable Oils for olive oil,[13] canola oil[12] or sunflower oil.[12] The total TFA content of the three types of sampled oils varied from 0.13-0.26%, 0.15-0.37% and 0.22-0.46% for olive, canola and sunflower, oil, respectively (Figure 1).

Table II: The inter-assay coefficients of variation between the different oils

Descriptor	Olive oil	Canola oil	Sunflower oil	Average
16:0	0.77	1.58	1.22	1.18
18:0	1.65	1.25	0.83	1.45
18:1 n-9	1.27	1.29	1.09	1.28
18:2 n-6	1.32	1.20	1.00	1.26
18:3 n-3	2.00	1.23	1.31	1.62
% TFA	1.19	1.18	1.05	1.18

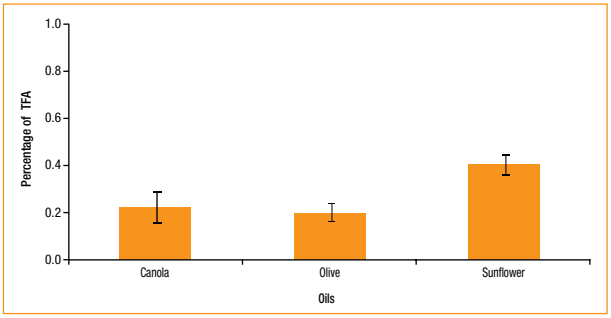
TFA: trans-fatty acid

Oxidation status of the oils

The oxidative status of the fresh unopened oils is displayed in Figures 2 a and b. CD and peroxide levels were measured as indicators of oxidation status. Desirable CD and peroxide levels are < 20 µmol/g[11] and < 10 meq O_2/kg for the seed oils, and < 20 meq O_2/kg for olive oil, as stipulated by the Codex Standard for Named Vegetable Oils.[12,13] None of the analysed oils contained oxidative products above the permissible level.

Discussion

Statements with the intention of provoking fear are often misinformed and unsound. Statements and opinions such as these are no exception in nutrition. Within the nutrition context, such statements simultaneously convey confusing and incorrect messages to the consumer, and in turn, compromise health and harm *bona fide* industry. A statement was made that South African seed oils are toxic, with no substantial scientific evidence to authenticate it. The results of our analysis have dispelled this myth.



TFA: trans-fatty acid

Figure 1: Total trans-fatty acid content of the selected South African oils

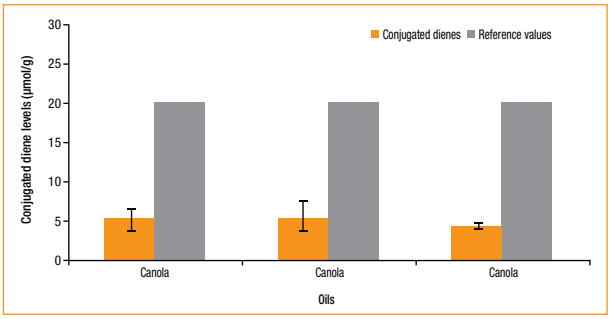
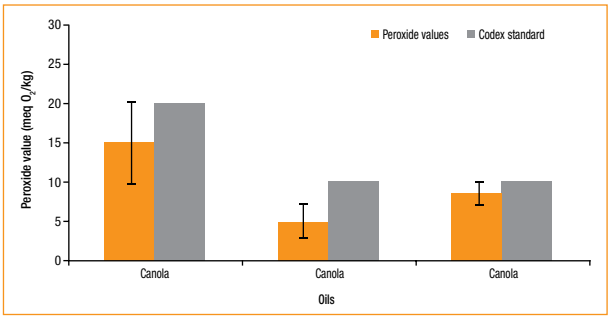


Figure 2 a: Oxidation status of oils in terms of conjugated diene levels



Codex Standard: Codex Standard for Named Vegetable Oils

Figure 2 b: Oxidation status of oils in terms of peroxide levels

All three types of analysed oils adhered to the respective Codex Standard for Named Vegetable Oils for specified fatty acid in terms of fatty acid composition. The statement raised concern about the erucic acid content of canola oil. Canola refers to an edible oil product derived from the seeds of several varieties of the rapeseed plant. The change in name, from "rapeseed" to "canola", serves to distinguish it from natural rapeseed oil, which contains a considerably higher erucic acid level. Scientists improved the quality of previous rapeseed cultivars through traditional plant breeding, which resulted in a commercially available canola cultivar, called *Brassica napus*. The term "canola oil" derives from Canadian oil (low acid), which refers to the low levels of erucic acid in this oil. Low erucic acid (< 2.2%) canola oil has been available since the late 1970s, and has been confirmed as safe for human consumption.[14] All of the canola oils analysed in this analysis contained ≤ 0.09% erucic acid (Codex Standard for Named Vegetable Oils < 2.2%).[12] Therefore, the statement made in popular literature about the toxic erucic acid content of canola oil is unjust and unscientific.

Another unscientific statement that was made was that mustard gas [bis(2-chloroethyl) sulphide] is derived from the rapeseed or canola plant. However, mustard gas is not chemically related to mustard oil, or any mustard plant, but is formed during a chemical reaction when sulphur chloride is treated with ethylene.[15] When used in an impure form, e.g. as a warfare agent, it is characterised by a yellow-brown colour, and has an odour that resembles that of a mustard plant, garlic or horseradish, hence the name.

Regarding the TFA content of the seed oils, TFA, per definition, is unsaturated fatty acid, with no less than one unsaturated, nonconjugated double bond in the *trans,* rather than the *cis,* configuration. TFA, mainly from hydrogenated vegetable oils, adversely affects the risk factors, i.e. insulin resistance, systemic inflammation, endothelial function and adiposity, associated with coronary heart disease (CHD). TFA isomers, such as C18:1 and C18:2, have been linked to more prominent adverse CHD effects than C16:1 TFA.[16] TFA is formed in the presence of a metal catalyst, usually nickel or platinum, when hydrogen gas is combined with PUFA oil at a high temperature over several hours.

The total TFA content of the unused sampled oils which we analysed varied from 0.13-0.26%, 0.15-0.37% and 0.22-0.46%. The World Health Organization recommends a TFA intake of not more than 1% of total energy intake, which equals 2.5 g of TFA in a 2 000-kcal diet. Therefore, the consumption of 2.5 g TFA derived from South African seed oils would mean that 1 250 ml olive oil, or 1 136 ml canola oil or 625 ml sunflower oil, would need to be ingested on a daily basis. The argument around the high TFA content of seed oils was based on a single publication on canola oils in the USA more than 21 years ago.[2]

Minute amounts of TFA can appear in olive oil,[17] canola oil[18] and sunflower oil[17] during deep fat frying. Consequently, a large amount of deep fat fried food needs to be consumed to contribute meaningfully to the dietary intake of TFA. It is also unlikely that TFA is formed during the frying process since a catalyst is necessary for hydrogenation to take place. It was reported in recent studies[19,20] that elevated levels of TFA in the oil after frying might be attributed to the release of TFA from pre-fried food into the frying oil. Moisture loss from the oil during frying should also be taken into consideration since vegetable oil may contain 0.1-0.2% moisture.[12,13] Water evaporates at 100 °C, and may therefore increase the concentration of the TFA that is already present in the oil. It is also significant that during the processing of sunflower and canola oil, the oil is heated to 230 °C with steam, and irrespective of such a high temperature, our results revealed very low TFA content in both these oils. Results from our laboratory showed that crude canola oil naturally contains around 0.097% TFA, while refined canola oil contains approximately 0.22% TFA, which is still well below the recommended levels for food.

The oxidation status of the freshly analysed sunflower, canola and olive oil was within the prescribed range, according to the respective Codex Standard for Named Vegetable Oils,[12,13] and therefore suitable for human consumption. However, frying, especially deep fat frying, changes the stability and quality of cooking oil, irrespective of the type of oil used. Chemical reactions, such hydrolysis, oxidation and polymerisation, contribute to the degradation of oil with deep fat frying. Frying time and temperature, replenishment of the oil, the quality of the frying oil, the type of fryer used, the presence of antioxidants, the amount of dissolved oxygen content in the oil, the degree of unsaturation, as well as the composition of the food fried in the oil, are factors which also affect the quality of oil during deep fat frying.[21] The more often oil is reused, the higher the level of degradation products in the oil, regardless of the type of oil used. Animal fat is also prone to degradation during cooking because it does not consist of saturated fat only, but is rather a combination of SUFA, MUFA and PUFA, in different ratios.

The most favourable ratio of omega-6 to omega-3 fatty acid of the analysed oil samples was found in canola oil. Since canola oil is an affordable oil with an appreciable omega-3 fatty acid content, it is capable of contributing significantly to omega-3 fatty acid intake in South Africans. The omega-6 to omega-3 fatty acid ratio in the canola oils varied between 2.0 and 3.0:1 (Table I), compared to other fat, such as pork lard (17.0-23:1),[22] avocado oil (13.0-17:1)[22] and olive oil (13.0:1.0). According to Simopoulos,[7] the desired dietary omega-6 to omega-3 ratio is 2.0-5:1.

Also, canola oil has a relatively high oleic acid content (60% of total fatty acid), and is a much cheaper food source than olive oil. Although sunflower oil has a very high omega-6 to omega-3 ratio (330,0:1.0), it contains a considerable amount of oleic acid, and can contribute significantly to the dietary intake of MUFA. Percentage wise, South African sunflower oil contains a comparable amount of oleic acid (23-33%) in relation to that in other sources of fat, such as commercial lard (37%) and butter (26%).[22]

An unexpectedly high prevalence of vitamin E deficiency was found in pre-schoolchildren in a recent clinical trial [Benade S (2015) personal communication]. This phenomenon was also reported in elderly communities in South Africa,[23] as well as in breastfeeding women with human immunodeficiency virus.[24] This might be attributed to a low intake of fruit, vegetables and vitamin E-containing seed oils, such as canola and sunflower oil. Vitamin E is essential for haem biosynthesis, acts as a modulator in the immune response, protects selenium-containing protein, and is a ubiquitous component in the lipid fractions of cell membranes and lipoprotein, where it has a potent antioxidant function.[25] Canola, sunflower and olive oil are sources of vitamin E, and contain 17.5 mg, 41.0 mg and 13.0 mg α-tocopherol per 100 g oil, respectively, while saturated fat

contains only a small amount of vitamin E per 100 g, versus lard (0.6 mg), butter (2.3) mg and coconut oil (0.09) mg.[22] Other rich sources of vitamin E include almonds and rice bran oil, but these sources are outside the price range considered to be affordable by most South Africans.

According to the Department of Agriculture, Forestry and Fisheries,[26] neither the canola nor sunflower oil produced in South Africa is GM. Canola oil was purchased from retail stores and screened for genetic modification in a study by Viljoen and Marx.[27] GM material was not found in any of the three analysed oils. The process of genetic modification affects the genes, protein and enzyme parts of the plant, while the oil remains intact.[28] If GM oil was consumed, only the refined, bleached and deodorised oil containing little to no protein would be consumed. Thus, human exposure to the protein through these oils would be minimal.[29] In addition, even if GM oil was available for human consumption in South Africa, a literature review revealed that there is no scientific evidence that GM seed oil from any sources represents a safety hazard to human health. In addition, there is no mention in any literature that GM oils are available in South Africa.

Conclusion

Seed oils are not only a good source of fatty acid, but also provide essential fatty acid in the diet. Furthermore, the cultivation of seed oil contributes significantly to job creation and social development in the areas where it is farmed. It was demonstrated in our analysis that South African seed oils contain a negligible amount of TNF, adhere to international recommendations with regard to erucic acid content, and are well within the safe range for oxidation products. Seed oils are also a rich dietary source of vitamin E. However, consumers should ensure that cooking oils are not overused, and must replenish them timeously. Failing to regularly replenish oils exposes the oil to chemical reactions, such hydrolysis, oxidation and polymerisation, which contribute to their degradation. Aspects on GM and the claimed association with mustard gas have also been addressed. Therefore, the results of this study indicate that South African seed oils are of good quality, are safe for human consumption, and should not be excluded from the diet. Therefore, the statement in *The Real Meal Revolution* that seed oils are toxic is incorrect and devoid of scientific substantiation.

Conflict of interest

The authors have no conflict of interest to declare.

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